United Nations A/AC.105/765

General Assembly

Distr.: General
14 August 2001

Original: English

Committee on the Peaceful Uses of Outer Space

Report on the United Nations/European Space Agency/Committee on Space Research Workshop on Data Analysis and Image-Processing Techniques

(Damascus, 25-29 March 2001)

Contents

		Paragraphs	Page
I.	Introduction	1-11	3
	A. Background and objectives	1-7	3
	B. Organization and programme	8-11	3
II.	Summary of presentations	12-54	4
	A. Remote sensing and geographic information systems: case studies	12-23	4
	1. Egypt: modelling the Western Desert environment using satellite data	12-13	4
	2. Libyan Arab Jamahiriya: land degradation and desertification	14-15	4
	3. Saudi Arabia: study of water resources in Al-Madinah al-Munawwarah	16	5
	4. Sudan: acquainting decision makers in developing countries with the potential uses of remote sensing technology	17-19	5
	5. Syrian Arab Republic: land use mapping and determining pollutant factors in the Al-Awage river basin using remote sensing techniques	20-21	6
	6. Syrian Arab Republic: remote sensing for agriculture and land resources	22-23	6

V.01-86540 (E) 041001 051001

B.	Remote sensing and geographic information systems: data analysis and image processing	24-43	6
	1. Digital image processing	24-25	6
	2. Use of remote sensing and geographic information systems in natural resource management	26-28	7
	3. Natural resource management using the geomatic approach	29-31	7
	4. Linear mixture modelling for vegetation mapping in dry lands	32-34	7
	5. Evaluation of texture-based classification of a single synthetic aperture radar image	35-36	8
	6. Combined classification of a SPOT-XS image using textural and multi-spectral information	37-42	8
	7. Role and retrieval of geophysical parameters in studying land surface processes	43	8
C.	Application of remote sensing in meteorology	44-47	9
	Overview of systems of operational meteorological satellites in geostationary and polar orbit	44-47	9
D.	Personal computer-based digital photogrammetry	48-51	9
E.	Hands-on remote sensing and geographic information systems at the General Organization of Remote Sensing	52-54	10

I. Introduction

A. Background and objectives

1. The Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), in particular through its Vienna Declaration on Space and Human Development, recommended that activities of the United Nations Programme on Space Applications promote collaborative participation among Member States at both the regional and the international level, emphasizing the development of knowledge and skills in developing countries.[1]

2. At its forty-third session, in 2000, the Committee on the Peaceful Uses of Outer Space endorsed the programme of workshops, training courses, symposiums and conferences planned for 2001.[2] Subsequently, the General Assembly, in its resolution 55/122 of 8 December 2000, endorsed the United Nations Programme on Space Applications for 2001.

3. Pursuant to resolution 55/122 and in accordance with the recommendation of UNISPACE III, the United Nations European Space Agency (ESA)/Committee on Space Research (COSPAR) Workshop on Data Analysis and Image-Processing Techniques was organized by the United Nations, ESA and the Government of the Syrian Arab Republic at the General Organization of Remote Sensing (GORS) in Damascus from 25 to 29 March 2001. GORS acted as host of the workshop on behalf of the Government of the Syrian Arab Republic.

4. The main objective of the workshop was to provide a forum for engineers, educators and scientists concerned with access, analysis and interpretation of satellite data. While the scientific and technical applications of satellite data may cover a wide range of topics, from environmental monitoring to astronomy and from meteorology to remote sensing, the basic techniques of satellite data processing with the necessary software are essentially common to those activities. The workshop studied data analysis and image-processing techniques so that the vast banks of such data that exist worldwide could be utilized by a larger number of engineers and scientists in developing countries.

5. The workshop provided a platform for interaction between engineers and scientists who generated satellite data for various scientific and technical applications and those, in particular in developing countries, who were involved in the access, processing, analysis and interpretation of satellite data for scientific research and practical applications in the areas of their expertise. The workshop equipped participants with an expert knowledge of the tools available for access, analysis and interpretation of data obtained by digital data acquisition systems for a variety of practical, educational and scientific purposes. Basic and advanced principles and methods were presented and reinforced with practical examples from everyday data access, analysis and interpretation operations. The workshop also fostered communication between users with a wide range of expertise in the production and use of software packages to pursue data management in remote sensing, geographic information systems (GIS), photogrammetry and their applications in natural resource management, in particular in monitoring water resources, desertification, land use, environmental pollution and ecosystem changes in arid areas.

6. The workshop also provided an opportunity to start preparations for the next workshop in the series, to be hosted by the Government of Nigeria, preferably at the African Regional Centre for Space Science and Technology Education—in English Language in Ile-Ife, Nigeria, in 2002.

7. The present report has been prepared for submission to the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space at its thirty-ninth session, in 2002. Participants have reported on the knowledge acquired and the work conducted during the workshop to the appropriate authorities of their Governments, universities and institutions. A number of papers presented at the workshop will be published in *Seminars of the United Nations Programme on Space Applications: Selected Papers from Activities Held in 2001* (ST/SPACE/7).

B. Organization and programme

8. The workshop was held at GORS, in Damascus, from 25 to 29 March 2001. It was attended by 56 engineers, educators and scientists from 15 countries,

Algeria, Austria, Egypt, Germany, India, Jordan, Lebanon, the Libyan Arab Jamahiriya, Morocco, Nigeria, Saudi Arabia, the Sudan, the Syrian Arab Republic, Tunisia and Yemen, as well as from the United Nations and ESA.

9. The United Nations and ESA provided financial support to defray the cost of international air travel and living expenses of 20 participants from developing countries. Room and board and local transportation for the same participants, as well as meeting facilities and equipment for the workshop, were provided by GORS.

10. The programme of the workshop had been developed jointly by the Office for Outer Space Affairs, GORS, ESA and COSPAR. Presentations made at the workshop covered satellite data analysis and image-processing techniques as used in the fields of remote sensing, meteorology and space science. Information on satellite data access, interpretation and archiving was also presented and demonstrations were made of appropriate software tools.

11. Opening addresses were made by representatives of GORS, the Office for Outer Space Affairs and ESA.

II. Summary of presentations

A. Remote sensing and geographic information systems: case studies

1. Egypt: modelling the Western Desert environment using satellite data

12. It was reported that Egypt had embarked on an ambitious project to reclaim land in the Western Desert, a part of the great African desert. The Toshka project would use the water resources of the Nile for reclaiming desert land. The project was also associated with agricultural activities for land reclamation, cultivation, food and agro-industrial activities, housing, transportation and supply of various forms of energy. The influence of climatic conditions on the above activities were not well documented or understood, but the arid environment and motion of sand dunes could greatly affect the sustained feasibility and economics of such activities. Proper climatic-related conditions, stressing appropriate use of passive and natural means, appeared to allow for better living conditions and also for considerable savings in the running costs of the project. However, such practices must rely on well-established and reliably verified environmental data suitable for design, monitoring and evaluation purposes.

13. The presentation described a proposal to use satellite data to construct a related sequence of environmental/climatic models suitable for use by the different activities mentioned at various levels of detail. That included macro-climatic, meso-climatic and simple micro-climatic model levels. The models incorporated digital image maps and meteorological databases to provide the basic model elements. A number of aerodynamic utilities, to provide surface wind speed and weathering conditions at selected sites, were integrated into the model for analysis and simulation purposes. The model relied heavily on modern techniques of data visualization to present model outputs for enhanced usability and user-friendliness. Coordination efforts with other entities working in related fields, such as desertification, meteorology, agriculture, architecture, archaeology, remote sensing and energy utilization, were a major concern of the proposal.

2. Libyan Arab Jamahiriya: land degradation and desertification

14. The presentation provided the background on available information concerning processes that caused and affected land degradation and desertification in the Libyan Arab Jamahiriya with emphasis on the Mediterranean coastal zone, where potential land for agriculture was located and where more than three quarters of the population were concentrated. National measures had been taken to combat desertification in the last four decades and further work was urgently required. An application of remote sensing and GIS to study land degradation of areas situated in the north-western region of the country was also included in the presentation. It indicated that scarcity of water (aridity), overgrazing and changing the range land to rain-fed agriculture had caused destruction of natural vegetation cover (reduction of bio-productivity and invasion of new species) and induced wind and water erosion. Increased human pressure on the use of localized underground aquifers caused sea water intrusion in the coastal zone.

15. In irrigated areas, the result of excessive irrigation and inefficient drainage had caused water logging and secondary salinization. Monitoring studies

in the El-Witia area (as a pilot project), which had been conducted at the Libyan Centre for Remote Sensing and Space Sciences in 1997, had shown the severe state of natural resource degradation in range lands of the coastal zone (52 per cent reduction in vegetation cover and 227 per cent increase in the formation of sand dunes over a 10-year period, from 1986 to 1996). Many measures had been taken to combat desertification in the last decades, including water development and conservation, wind and water erosion control, land reform, reclamation and development and several social and legal actions. Some of the past and ongoing anti-desertification measures taken had succeeded, while others were not suitable. Those measures must therefore be evaluated in order to provide a clear perspective for future programmes. The presentation also concentrated on the importance of modifying water resource policies so as to take into account the growing water scarcity in the country and the role of research, education and training in combating desertification and stopping land degradation more efficiently.

3. Saudi Arabia: study of water resources in Al-Madinah al-Munawwarah

16. The main objective of the study presented was the assessment of water resources in the city of Al-Madinah al-Munawwarah and its vicinity in order to find additional supplies of groundwater to meet the increasing demand for drinking water. Satellite images (including from the Landsat-5 thematic mapper (TM) and Système pour l'observation de la Terre (SPOT) satellites) had been processed to study the geology of the area. Three-dimensional images had been generated and used for detailed studies of the topography and water drainage systems. Geophysical surveys, including magnetic and resistivity surveys, had been made, as well as pumping tests of a number of water wells available in the area. That had been undertaken to discover the depth of the basement and hence the thickness of sediments as well as the depth and size of aquifers. Mathematical modelling had also been carried out to determine the current and future potential of aquifers. A number of sites that had drinking water potential and could be used to meet the increasing demand for drinking water had been located in the area under study. The project had been supported in part by the Al-Madinah al-Munawwarah Drinking Water Authority.

4. Sudan: acquainting decision makers in developing countries with the potential uses of remote sensing technology

17. It was stated that the Sudan, with an area of 2.5 million square kilometres, was the largest country in Africa, with diversified climates and natural resources. The utilization of those resources for a developing country such as the Sudan could be very difficult, as technology was at the heart of the development process. Thus, the need to utilize technology made the emerging use of remote sensing of vital importance, because it was one of the widely used advanced techniques. Whether on a local, regional or global scale, countries' demands for Earth resources were increasing rapidly. That situation required sound management of those resources, which could be attained by means of remote sensing.

18. The objective of the study was to acquaint decision makers in developing countries, and in particular in the Sudan, with the potential of satellite technology in obtaining vital information on crops, land use, marine and coastal environments, mineral exploration and so on and to emphasize the importance of such data in recent and future developments. The study had shown the application and usefulness of remotely sensed data for different natural resources and environmental aspects as a way of providing orientation for policy makers, planners, administrators and researchers. It has also revealed the need to use remote sensing for a developing country such as the Sudan, as it was a quick and practical tool for assessing, evaluating and monitoring the environment and natural resources. The results of integrating remote sensing in the Sudan into research, application and education would enhance the development of science and technology. Using remote sensing, it had been discovered that, in 1997, 18 per cent of the range lands in semi-arid regions of central Sudan had changed to cultivated lands, causing remarkable land degradation. In 1985, studies using remote sensing in western Kordofan had shown that no ecological zones had shifted southward; boundaries between different vegetation zones seemed to be the same as they had been 80 years ago.

19. The study recommended that the usefulness of remote sensing technology, augmented by GIS, for planning and development in developing countries be presented in a way that was convincing to decision

makers to support remote sensing applications. Most developing countries lacked the facilities for remote sensing. The study therefore recommended that those countries be provided with the necessary aid to establish remote sensing systems.

5. Syrian Arab Republic: land use mapping and determining pollutant factors in the Al-Awage river basin using remote sensing techniques

20. The objective of the study was to carry out an ecological survey for the Al-Awage river basin (which is considered one of the most important sources of water for Damascus) using remote sensing techniques and GIS. The study focused on the following issues:

(a) Vegetation distribution maps on the scale of 1:100,000 displaying the density and distribution of natural and cultivated vegetation cover in the basin region. The mapping also showed the correlation of vegetation presence with river water in three different combinations;

(b) Land use maps on the scale of 1:100,000, which made possible the determination of pollutants and other factors affecting the Al-Awage basin in general.

21. A number of recommendations and necessary proposals were submitted on the basis of the results of the study with a view to controlling pollution and to conserving and protecting both human health and the environment in the Damascus basin.

6. Syrian Arab Republic: remote sensing for agriculture and land resources

22. It was reported that remote sensing techniques had great importance in agricultural studies and land resource management. In that domain aerial photos and space images, which were recorded by electronic sensors or radar, were the tools that could be used to identify, monitor, assess and map agricultural wealth and land resources. Some of those activities were being carried out in the Syrian Arab Republic by GORS. The following case studies had been undertaken:

(a) Land use mapping in the west and south of the country;

(b) Land cover mapping;

(c) Soil survey and land classification in the west;

(d) Monitoring of land degradation in selected areas;

(e) Assessment of the land resources of the north-east;

(f) Range land monitoring and assessment in the Syrian grasslands;

(g) Forest mapping in the Syrian coastal mountains.

23. The studies had demonstrated that remote sensing was a valuable tool in such applications and that remote sensing and GIS integration was essential to establishing databases for agriculture and land resource management.

B. Remote sensing and geographic information systems: data analysis and image processing

1. Digital image processing

24. Digital image processing involved the manipulation and interpretation of digital images from remotely sensed data. In 1972, the United States of America had launched Landsat 1 and the digital image had become widely available for land remote sensing applications. There were various sources of digital image data, ranging from commercial Earth observation satellite systems, meteorological satellites and airborne scanned data to airborne digital camera data. All of those forms of data could be processed and analysed using digital image-processing software techniques.

25. Digital image processing often involved procedures that could be mathematically complex. However, the objective of the presentation was to introduce the basic principles of digital image processing. Digital image processing involved the following:

(a) Remote sensing data import;

(b) Radiometric correction;

(c) Geometric correction;

(d) Image enhancement;

(e) Image classification;

(f) Map generation (for output of maps).

2. Use of remote sensing and geographic information systems in natural resource management

26. It was pointed out that the rapid progress of remote sensing technology had made space data a very accurate and up-to-date spatial data resource that made it possible to prepare cartographic and thematic semi-detailed maps and to perform different types of digital processing and classification with high precision.

27. Since the technology of GIS was based upon integration and a multi-level approach—involving mainly computer science, mathematics, planning and Earth science—remote sensing had become an important source for information that was essential for database establishment. Remote sensing had thus become the cornerstone of GIS applications and information technology.

28. GIS, which was based on the use of computers and applied software, was now considered the new technology for database establishment. Those databases consisted of different thematic maps of various spatial resolutions and attributed physical parameters. Based on the processing and analysis of the databases, solutions and choices were obtained and used in planning and modelling for natural resource management.

3. Natural resource management using the geomatic approach

29. The presentation on this subject provided an overview of the image-processing and data analysis approach for natural resource management through case studies on forest mapping and inventory and evaluation of soil erosion.

30. The first case concerned the utilization of Landsat TM images to establish forest maps. The approach adopted was based on photo-interpretation to obtain the required information. Several processing techniques were used: geometric correction, contrast enhancement and classification. Exogenous data (existing maps and field surveys) were also used to draw the final maps.

31. The second project utilized a combination of remote sensing and GIS techniques to develop erosion risk maps. The presentation focused on the methodologies used to generate thematic maps (temperature, run-off, soil, slope and exposure, land use and vegetation index) to be integrated with models for erosion estimation. The role of GIS in data analysis and management was also described.

4. Linear mixture modelling for vegetation mapping in dry lands

32. Mapping vegetation cover in dry lands posed a problem because of the high contribution of the soil to the background spectral properties of each pixel as a result of the low vegetation density. Mixed pixels were very common in such an environment because vegetation cover very rarely reached 100 per cent, making most pixels a mixture of vegetation, fine sediments (soils) and stones. Consequently, mixed pixels were the main cause of classification error in dry lands because image classification techniques assumed pixels to be pure. Unfortunately, that was not the case in dry lands where the classes of land cover were continuous rather than discrete. Furthermore many classes that were commonly defined as "urban" or "bare rock" were often spectrally heterogeneous, being a mosaic of numerous spectrally different materials and because rock outcrops exhibited topographies that led to variations in illumination. The result of such within-class heterogeneity was that classes with high variance suffered significant levels of misclassification. Furthermore, classification approaches could not provide objective vegetation maps because of the human intervention required in highly interactive processes such as spectral class definition.

33. It was evident that a method for mapping vegetation in dry land areas was needed that: (a) used the maximum amount of spectral information; (b) took into account the fact that most pixels were mixtures; and (c) neutralized the effects of the atmosphere, as well as problems of illumination and observation geometry. The linear mixing model using the concept of spectra satisfied all of those conditions.

34. In the presentation, the assumptions underlying linear mixing were discussed and a solution to the linearity of the mixing problem was proposed. A report was then made of the results when the procedure was applied to a number of TM images to generate different maps of the study area.

5. Evaluation of texture-based classification of a single synthetic aperture radar image

35. In the presentation on this subject, a comparison was made between two classification methods. The first method used a combined classification based on textural and radiometric information and the second used only radiometric information. Textural analysis was made by using the gray level co-occurrence matrix (GLCM), for which contrast, entropy, homogeneity, correlation, local homogeneity, directivity and uniformity were used.

36. It was demonstrated that a significant improvement in classification accuracy occurred if textural features were used as additional inputs to the radiometric information. However, neither method was able to discriminate between targets situated in shaded areas and areas directly exposed to the radar signal. The overall classification accuracy obtained using the GLCM method was 55 per cent, a significant improvement over the classification using only radiometric data, which gave an accuracy of 35 per cent. Results could be improved if the effect of macro relief was eliminated in order to isolate the micro relief that characterized textural information.

6. Combined classification of a SPOT-XS image using textural and multi-spectral information

37. Texture analysis played an important role in image processing, image classification and in the interpretation of remotely sensed data. The GLCM approach was one of the most popular statistical methods used in practice to measure the textural information of images.

38. The objective of the study was to combine textural and multi-spectral information in order to carry out a combined classification using a SPOT-XS image.

39. A combined cartographic procedure, based on a semi-automatic approach using the procedures of supervised classifications of the same scene in SPOT-XS, were applied to the Foum Tillicht district in the eastern High Atlas of Morocco.

40. The combination of textures on a SPOT-XS image and spectral properties on the same SPOT-XS image made it possible to improve supervised classifications, resulting in better discrimination of the structures and geological formations.

41. Combining a GIS of maps based on existing cartographic data, the digital elevation model (DEM) and the information obtained made possible a geological inventory of the area and led to a significant improvement over existing maps.

42. The texture of the SPOT-XS image was related directly to the geomorphology and form of the relief. Thus, superposition of the geological map obtained in the study made it possible to present the geological map in block diagram form, producing a three-dimensional image of considerable use to geologists.

7. Role and retrieval of geophysical parameters in studying land surface processes

43. Anthropogenic activities had become a significant force affecting the functioning of the Earth system. Climate, the global cycles of carbon and water and the structure of natural ecosystems were all closely linked. Major changes in any one of those systems affected the others. Thus, there was a need to study and model the significant interactions of biological, chemical and physical processes that governed changes in the Earth system and were most susceptible to human influence. Satellite data sets provided a unique opportunity to retrieve many important geophysical parameters. In the retrieval scheme, understanding the physics of the problem was of paramount importance. The study presented dealt with the utility of satellite data in estimating surface albedo, surface emissivity, surface temperature and related physical parameters. Those parameters were derived using various methodologies. Algorithms had been used to estimate surface albedo by effectively utilizing satellite data information. An attempt had been made to derive narrowband and broadband emissivity. The concept of vegetation indices had also been studied as they were the inputs for estimating surface emissivity. The measurement of those parameters contributed to knowledge about physical surface temperature. Evapotranspiration, a significant component of both water balance and energy balance, was also estimated using satellite data. Overall, an effort was made to estimate land surface processes that were otherwise inaccessible from ground-based measurements.

C. Application of remote sensing in meteorology

Overview of systems of operational meteorological satellites in geostationary and polar orbit

44. It was stated that, for the past two decades, a fleet of operational meteorological satellites had been circling the Earth, providing a stream of invaluable data in support of operational meteorology and many other disciplines. An international network of satellites in geostationary orbit, stationed far above the equator, provided images of mid-latitudes and the tropics each half hour, day and night. Systems of satellites in lower orbits were flying around the Earth from pole to pole every 100 minutes, observing the planet twice a day with an extraordinary range of powerful sensors.

45. During that period, the applications of such satellites had grown far beyond the dreams of those who had established the systems more than 20 years ago. They had become essential, not only for meteorology, but also for climate monitoring purposes and for monitoring the health of the oceans, land surfaces and the planetary atmosphere. The range of applications was so large that it had become difficult to keep track of what the satellites could be used for. Few could have imagined, for example, that planned meteorological satellites would measure with high precision the speed and direction of the surface winds over the oceans of the entire planet or that the same satellite could be used to track migrating wildlife and to monitor vegetation growth. Even after becoming aware of those possibilities, the potential user might have no idea which instruments were used for a given purpose, how the data were processed to achieve the required information or which entity around the world was in a position to provide further information.

46. The global system of operational meteorological satellites included a constellation of at least five satellites evenly spaced around the equator in geostationary orbit and at least two satellites in near-polar orbits. Geostationary satellites flew at an altitude of about 36,000 kilometres and each had the capability to provide almost continuous imagery and communications support over a wide region of the planet.

47. Each satellite could generate full Earth disc images covering nearly one quarter of the Earth's surface, day and night. The polar orbiting satellites flew in much lower orbits, typically at around 850 kilometres, with the orbital plane at an angle of about 80° to that of the equator. Polar orbit satellites were designed to look down on the entire surface of the Earth every day. Satellites in polar orbit circle the Earth, passing above the North and South poles several times a day. As the satellite looped around the globe, the Earth seemed to rotate under the orbit. The satellite passed over the entire surface daily.

D. Personal computer-based digital photogrammetry

48. The introduction of digital photogrammetry had changed the world of photogrammetry completely. It was no longer necessary to use the expensive hardware components formerly required, if digital images were available. Only a scanner was required if traditional aerial photos were to be used. It was reported that the University of Hanover, in cooperation with the University of Düsseldorf, both located in Germany, had developed a software system that could carry out the following functions: measurement of image coordinates as input for block adjustment, bundle block adjustment, measurement of a digital stereo pair, generation of DEM by automatic image matching, filtering of elements not belonging to a DEM, generation of orthophotos, mosaics of orthophotos and the processing of DEM. The processing of DEM included the computation of contour lines, three-dimensional representation and more. The whole program system was personal computer (PC)-based and simple to handle. The whole world of photogrammetry was thus available on standard PCs with very little effort.

49. Photos were information about the imaged objects, but information without geometric reference was useless. Photogrammetry provided the three-dimensional reference for context information. For a long time, analog and analytical photogrammetry had dominated, both were proven techniques, but they required expensive instruments. Even standard PCs were now powerful enough to handle aerial or space images with full resolution, such that digital photogrammetric applications could be handled on simple PCs. The only hardware component needed for digital photogrammetry beside the computer was the image

scanner, if analog images needed to be used. To take advantage of the full accuracy range of the photogrammetry, special photogrammetric scanners were required because desktop publishing scanners were limited to an accuracy of approximately +/-50 µm, even if the resolution of the photograph might be higher.

50. The important advantage of digital photogrammetry was the possibility of automation. Automatic image matching was no longer time-consuming and was much faster than manual measurement of DEM.

51. All the steps required from the digital image to the final result were available in the SIDIP programme system, developed by the University of Hanover in cooperation with the University of Düsseldorf.

E. Hands-on remote sensing and geographic information systems at the General Organization of Remote Sensing

52. GORS was constituted in the Syrian Arab Republic in February 1986. Located in the outskirts of Damascus, GORS cooperated with governmental bodies, countries of Western Asia and international bodies. The Organization carried out studies and projects on remote sensing applications for geology, hydrology, hydrogeology, agriculture, urban planning, environment, meteorology and archaeology by utilizing Landsat and SPOT images and published on a regular basis a space atlas of Syria, a glossary of remote-sensing terminology in various languages and journals of remote sensing.

53. A major objective of GORS was to support sustainable development while safeguarding the country's environment. That required optimal management of natural resources, which in turn depended on the availability of reliable and timely information at the national and regional levels. Remotely sensed data played an increasingly important role as a source of the information needed for sustainable management of natural resources and for environmental protection. Through GIS, remote sensing data could be integrated with data from other sources to facilitate the efforts of resource managers, planners and policy and decision makers in obtaining the relevant information they needed. In order to facilitate such sustainable resource management in countries of Western Asia, GORS conducted courses and symposiums in remote sensing and GIS as applied to various Earth resource disciplines. The venue of the workshop, GORS, was a premier training institution in the region of Western Asia that had trained individuals from the Syrian Arab Republic and elsewhere over the last two decades. GORS was well equipped with state-of-the-art computing facilities such as sophisticated personal computers and workstations with modern peripherals and software for remote sensing and GIS. It also had laboratories for ground truth equipment. Participants at the workshop had the opportunity to familiarize themselves with the computer hardware and software available at GORS during hands-on sessions for satellite data reduction, processing and analysis, and applications.

54. In the hands-on sessions, special attention was drawn to a recent study of groundwater exploration by remote sensing in the Syrian Arab Republic, conducted jointly by GORS, Italy and the Food and Agriculture Organization of the United Nations. The study had indicated that the integration into GIS of data extracted from Earth observation satellites with those traditionally collected, coupled with selected field investigations and geological knowledge of the area under investigation, provided a powerful tool in the search for groundwater.

Notes

[1] *Report of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space*, chap. I, resolution 1, part I, sect. 1 (e) (ii), and chap. II, para. 409 (d) (i).

[2] *Official Records of the General Assembly, Fifty-fourth Session, Supplement No. 20* and corrigendum (A/54/20 and Corr.1), para. 52.

United Nations A/AC.105/765/Corr.1

General Assembly

Distr.: General
1 November 2001

Original: English

Committee on the Peaceful Uses of Outer Space

Report on the United Nations/European Space Agency/Committee on Space Research Workshop on Data Analysis and Image-Processing Techniques

(Damascus, 25-29 March 2001)

Corrigendum

1. Add a new paragraph 2 to read as follows:

   2. Pursuant to that recommendation, three workshops have already been organized:

   (a) United Nations/International Society for Photogrammetry and Remote Sensing Workshop on Remote Sensing Data Analysis Methods and Applications, held in Washington, D.C., on 6 and 7 August 1992 (see A/AC.105/545 and Corr.1);

   (b) United Nations/European Space Agency/Committee on Space Research Workshop on Data Analysis Techniques, held in São José dos Campos, Brazil, from 10 to 14 November 1997 (see A/AC.105/687);

   (c) United Nations/European Space Agency/Committee on Space Research Workshop on Satellite Data Reduction and Analysis Techniques, held in Dehra Dun, India, from 27 to 30 November 2000 (see A/AC.105/746).

   and renumber the subsequent paragraphs accordingly.

2. Add the following text at the end of paragraph 10:

   The following documents were used as reference texts during the workshop:

   Brockwell, P. J., and R. A. Davis, Time series: theory and methods. 2. ed. New York, Spring-Verlag, 1991.

V.01-88211 (E) 021101 051101

Gupta, R. K., and S. Jeevananda Reddy, eds., Symposium proceedings; advanced technologies in meteorology (CR-ROM). New Delhi, Indian Meteorological Society/Tata McGraw-Hill Publishing, 2000.

Starck, J.-L., F. Murtagh and A. Bijaoui, Image processing and data analysis; the multi-scale approach. Cambridge, Cambridge University Press, 1998.

United Nations A/AC.105/766

General Assembly

Distr.: General
4 December 2001

Original: English

Committee on the Peaceful Uses of Outer Space

Report on the Tenth United Nations/European Space Agency Workshop on Basic Space Science: Exploring the Universe; Sky Surveys, Space Exploration and Space Technologies

(Reduit, Mauritius, 25-29 June 2001)

Contents

		Paragraphs	Page
I.	Introduction	1–12	2
	A. Background and objectives	1–7	2
	B. Programme	8–9	2
	C. Attendance	10–12	3
II.	Observations and recommendations	13–32	3
	A. Space exploration	15–18	3
	B. Sky surveys	19–20	3
	C. Education, training and services	21–27	4
	D. Space technologies	28–32	5
III.	Overview of the series of United Nations/European Space Agency workshops on basic space science	33–37	6
	A. United Nations/European Space Agency workshops on basic space science, 1991-2001	34	6
	B. Regional distribution of countries or areas and number of individuals who requested and received information on the results of the United Nations/European Space Agency workshops on basic space science in 2001	35	6
	C. Projects pursued through the series of United Nations/European Space Agency workshops on basic space science, 1991-2000	36	6
	D. Contact addresses and published results of United Nations/European Space Agency workshops on basic space science, 1991-2000	37	6
IV.	Mauritius Radio Telescope	38–46	6

V.02-89332 (E) 080102 090102

I. Introduction

A. Background and objectives

1. The Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) and the Vienna Declaration on Space and Human Development recommended that activities of the United Nations Programme on Space Applications promote collaborative participation among Member States at both the regional and international levels, emphasizing the development of knowledge and skills in developing countries.[1]

2. At its forty-third session, in 2000, the Committee on the Peaceful Uses of Outer Space endorsed the programme of workshops, training courses, symposia and conferences planned for 2001.[2] Subsequently, the General Assembly, in its resolution 55/122 of 8 December 2000, endorsed the United Nations Programme on Space Applications for 2001.

3. Pursuant to resolution 55/122 and in accordance with the recommendation of UNISPACE III, the Tenth United Nations/European Space Agency (ESA) Workshop on Basic Space Science: Exploring the Universe; Sky Surveys, Space Exploration and Space Technologies was organized by the United Nations, ESA and the Government of Mauritius at the University of Mauritius, in Reduit, Mauritius, from 25 to 29 June 2001. The workshop was co-organized by the Centre national d'études spatiales of France, the German Space Agency (DLR), the National Aeronautics and Space Administration (NASA) of the United States of America, the National Astronomical Observatory of Japan and the Planetary Society.

4. The workshop continued the series of United Nations/ESA workshops on basic space science organized for the benefit of developing countries that was initiated in 1991 (see table 1).

5. The main objective of the workshop was to provide a forum to highlight recent scientific results obtained using ground-based and space-borne observatories in studies of the stars and the far reaches of the universe. Satellite missions constitute an impressive means of studying all aspects of basic space science from space as a complement to studies being done from the ground. The question of the large volumes of data generated by such missions was discussed in relation to changing research needs within the scientific community, as was how access to the important databases maintained by major space agencies could be facilitated. The importance of data research and education based on space missions was discussed, together with the relevance of such missions to the needs of developing countries wishing to participate actively in the voyage of discovery through the universe.

6. The present report was prepared for submission to the Committee on the Peaceful Uses of Outer Space at its forty-fifth session and to its Scientific and Technical Subcommittee at its thirty-ninth session. A number of papers presented at the workshop will be published in *Seminars of the United Nations Programme on Space Applications: Selected Papers from Activities Held in 2001* (ST/SPACE/7).

7. During the workshop, the National Commission on Space Activities (CONAE) of Argentina announced that it would be prepared to host the Eleventh United Nations/European Space Agency Workshop on Basic Space Science at the Mario Gulich Institute for Higher Space Studies in Cordoba, in cooperation with the University of La Plata, Cordoba, Argentina, from 9 to 13 September 2002.

B. Programme

8. At the opening of the workshop, introductory statements were made by representatives of the Government of Mauritius, the University of Mauritius, ESA and the United Nations. The workshop was divided into scientific sessions, each focusing on a specific issue. Presentations by invited speakers describing the status of their findings in research and education were followed by brief discussions. Fifty-two papers were presented by invited speakers from both developing and industrialized countries.

9. The workshop sessions focused on (a) sky surveys; (b) from solar/planetary systems to galactic/extragalactic systems; (c) data manipulation, databases and multi-wavelength analysis; (d) education with and networking of telescopes, with special reference to the southern hemisphere; and (e) utilization of space science and technologies and their benefits to society. Poster sessions provided an opportunity to focus on specific problems and projects in basic space science.

C. Attendance

10. Researchers and educators from developing and industrialized countries in all economic regions were invited by the United Nations and ESA to participate in the workshop. Participants held positions at universities, research institutions, observatories, national space agencies, international organizations and in private industry and were involved in all the aspects of basic space science covered by the workshop. Participants were selected on the basis of their scientific background and their experience with programmes and projects in which basic space science played a leading role.

11. Funds provided by the United Nations, ESA and the University of Mauritius were used to cover travel and living costs of participants from developing countries. Some 65 specialists in basic space science attended the workshop.

12. The following 28 Member States were represented at the workshop: Austria, Canada, Chile, China, Denmark, Egypt, Ethiopia, France, Germany, Hungary, India, Italy, Japan, Mauritius, Mexico, Netherlands, Norway, Romania, Russian Federation, South Africa, Spain, Sri Lanka, Syrian Arab Republic, Uganda, United Kingdom of Great Britain and Northern Ireland, United States of America, Yemen and Zambia.

II. Observations and recommendations

13. The important initiatives arising from previous United Nations/ESA workshops on basic space science and their fruitful promotion in Africa were noted by the participants, as also the importance of the regional centres for space science and technology education affiliated with the United Nations in providing the essential knowledge for promoting various programmes in space science and technology.

14. Participants of the workshop reviewed in four working groups the observations and recommendations of past United Nations/ESA workshops on basic space science: (a) space exploration; (b) sky surveys; (c) education, training and services; and (d) space technologies.

A. Space exploration

15. Given the steady progress in space science and technology in the past decades, the scientific goal is the quest for knowledge about the structure and evolution of the universe, in particular, to learn more about the solar system, which is fundamental for humanity. The technical gains, technological challenges and spin-offs of space exploration for both industrialized and developing countries are enormous.

16. Space exploration by individual developing countries alone is very often difficult to achieve. Cooperation between developing and industrialized countries is essential, in particular in view of the fact that the international space community is witnessing a large influx of data from different space probes where space scientists from developing countries can contribute in an important way.

17. Associated with the concept of the world space observatory (for the ultraviolet region of the electromagnetic spectrum) (WSO/UV), an international centre for astronomy could be established—similar in spirit to the Abdus Salam International Centre for Theoretical Physics in Trieste, Italy—that would provide opportunities to space scientists from developing and industrialized countries alike to undertake joint research projects.

18. Participants noted that nearly all the data by spacecraft operated by ESA, NASA and the Institute of Space and Astronautical Science of Japan in the field of solar physics were available in public archives. Solarsoft, a solar data analysis package, was widely used. To allow a wider distribution, the participants recommended reviewing the possibilities of developing Solarsoft into a complete package that could be made available eventually as a freeware set of solar data analysis tools.

B. Sky surveys

19. Participants noted the importance of sky surveys. In particular, the emerging need for multi-wavelength astronomy, ranging from radio, infra-red, optical, X-rays to gamma rays, including neutrino and gravitational wave astronomy, provides a rich opportunity for astronomers from developing countries to be encouraged to carry out research, training and

education. South-South collaboration involving the Indian Ocean countries on the rim and African countries could be envisaged; for example, collaboration between the Mauritius Radio Telescope and the Southern African Large Telescope or other optical radio observatories in southern Africa, could be explored.

20. Participants welcomed the establishment of an international implementation committee, the World Space Observatory Implementation Committee, for the WSO/UV and the progress made in discussions among several space agencies and interested countries. Further development of the project, including wider participation, should be encouraged.

C. Education, training and services

21. Participants recognized that the area of space science was of a multidisciplinary nature, since it involved modern technologies in electronics, sensor devices and imaging, information technologies, World Wide Web-based technologies, basic science, analytical techniques and so on. Therefore, the introduction of the subject at the primary, secondary and tertiary levels of education should be addressed by all countries in order to face future challenges. Education, training and research should not be compartmentalized. They were interconnected and neglecting any one of them would lead to deficiency in the development of space science in a country.

22. Mauritius carried out diverse activities, which could be used as an example for other developing countries on the range of space activities that could be used to develop a rich basic space science programme. Such activities were (a) the Mauritius Radio Telescope project (since 1989), being undertaken in collaboration between India and Mauritius (detailed information in sect. IV below); (b) the Mapping Mauritius Project, using remote sensing and geographic information systems (GIS) (since 1997), in collaboration between the University of Mauritius and Phillips University, Marburg (Germany); (c) the interconnection of education, research and training at the University of Mauritius at both the undergraduate and the postgraduate level; and (d) the development of new tools for handling astronomical data based on image-processing techniques using GIS for the classification of galaxies using dynamic neural networks.

23. However, one should caution that a particular role model should not be pushed in other countries or regions. What worked in one region at one point of time would not necessarily suit another region at some other point of time. Developing basic space science education should be encouraged. In addition, if adequate research facilities were not available in a country, students would not find required challenges and would have no role models to look up to for further motivation. Thus, careful career planning for scientifically educated people, keeping in mind the local environment, must be an integral part of the development process.

24. The establishment of an African institute of space science as a distributed organization would act as a source of vision and strategy to promote the development of basic space science throughout Africa and would be a major step towards extending the participation of developing countries in Africa in basic space science, which could possibly in turn accelerate the integration of spin-off benefits of space science into society. The institute could benefit from the previous experience obtained in the regional centres for space science and technology education affiliated with the United Nations. Participants recommended that African Governments, while developing and fostering national basic space science programmes, give due consideration to supporting the establishment of an African institute of space science, as appropriate to their needs, and that serious consideration be given to the possible benefits of affiliating national programmes to the institute.

25. The participants noted the great value of NASA's Astrophysics Data System in providing access to astronomical literature. Participants urge industrialized countries to ensure continuing support for free access to the system and urged developing countries to utilize fully the services provided by it.

26. Having in mind the observations and recommendations of past United Nations/ESA workshops on basic space science, participants discussed the Network of Oriental Robotic Telescopes project and made the following observations and recommendations:

(a) Many countries affiliated to the Network project were progressing in terms of education by developing youth programmes, scientific clubs, secondary school programmes and courses at university levels;

(b) However, more countries with well developed activities in astronomy, astrophysics and space science, should introduce basic space science courses into their university curricula and should train young space scientists, astronomers, astrophysicists, programmers, engineers and technicians in their laboratories or observatories for appropriate periods of time. It was appreciated that the development of cooperative scientific projects through PhD work and continuous collaborations between universities in developing and industrialized countries was the best way to develop basic space science;

(c) French and Libyan astrophysicists were developing an educational and scientific cooperative programme for the 2.3-m national telescope at the University of Benghazi. The Islamic Republic of Iran had joined the Network of Oriental Robotic Telescopes with a project of a 2-m telescope with around 40 scientists, including MSc and PhD students;

(d) Eastern African countries (such as Ethiopia, Kenya and Madagascar) should carry out analysis of meteorological satellite data and site prospecting investigations on their high mountains in an effort to locate the best observational sites for middle- or large-size telescopes.

27. The participants noted that regional astronomical newsletters were published and distributed electronically through the World Wide Web and in hard copy on a regular basis, as recommended and supported by the United Nations/ESA workshops since 1996:

(a) *Africa*. The newsletter *Africa Skies/Cieux Africains* (http://www.saao.ac.za/~wgssa/) was published in a collaborative effort by the South African Astronomical Observatory and the Observatoire Midi-Pyrenées (France);

(b) *Asia and the Pacific*. The newsletter *Teaching of Astronomy in Asia-Pacific Region* was published by the National Astronomical Observatory of Japan;

(c) *Latin America and the Caribbean*. The newsletter *Astronomia Latino Americana* (http://www.astro.ugto.mx/~ala/) was published by the University of Guanajuato (Mexico);

(d) *Western Asia*. Preparations were progressing for the publication of a regional astronomical newsletter under the editorial supervision of an astronomical institute in Saudi Arabia.

D. Space technologies

28. Participants observed that the coordinated effort of the series of workshops on basic space science held under the auspices of the United Nations and ESA served as a catalyst:

(a) To promote the development of space technology in developing countries;

(b) To make possible cooperative efforts between countries, which would minimize the investment required by individual countries.

29. Participants noted that the cost of space technology had decreased considerably during the past decades and felt that Governments of developing countries should be encouraged to fund appropriate space science programmes for their respective countries in order to enjoy the benefits to be derived from them.

30. Participants recommended the development of on-line modular courses in space technology at the undergraduate and graduate levels to meet developing countries' needs for basic space science education, preferably in local languages.

31. Participants also recommended that developing countries implement curricula to prepare personnel to operate space science programmes.

32. The participants of the workshop recommended considering low-cost nano-satellites as a viable start-up for space projects for developing countries. Such projects could have a direct impact on the decision makers of developing countries and could provide a boost for furthering space science research projects.

III. Overview of the series of United Nations/European Space Agency workshops on basic space science

33. At the request of the international organizing entities (see para. 3), principal national organizers (see table 4) and participants of United Nations/ESA workshops on basic space science, respectively, information on the workshops held between 1991 and 2000 was gathered for the preparation of an assessment of the achievements of the workshops that could be finalized in 2001-2002. Subsequently, the results of such an assessment exercise could be brought to the attention of countries interested in the development of space science at the national, regional and international levels. Tables 1-4 have been compiled by participants of the workshops in cooperation with the principal national organizers of the host countries of all past United Nations/ESA workshops on basic space science.

A. United Nations/European Space Agency workshops on basic space science, 1991-2001

34. Table 1 contains information on host countries, their regional distribution, the number of participants and countries participating in United Nations/ESA workshops on basic space science between 1991 and 2001. The document symbols of the United Nations reports on the workshops and their titles are also provided.

B. Regional distribution of countries or areas and number of individuals who requested and received information on the results of the United Nations/ European Space Agency workshops on basic space science in 2001

35. The regional distribution of countries or areas and the number of individuals who requested and received information on the results of the United Nations/ESA workshops on basic space science in 2001 are shown in table 2. The addresses of the individuals in their respective countries have been used for the mail and electronic mail (e-mail) distribution of regional astronomical newsletters as described in paragraph 27. The same addresses have been provided to national and international astronomical organizations for dissemination of scientific information.

C. Projects pursued through the series of United Nations/European Space Agency workshops on basic space science, 1991-2000

36. Projects worked on at and follow-up projects pursued through the series of United Nations/ESA workshops on basic space science from 1991 to 2000 are identified in table 3. If available, World Wide Web addresses are provided from which detailed information on the respective project can be retrieved. Information on the projects is also contained in the United Nations reports on the workshops listed in table 1.

D. Contact addresses and published results of United Nations/European Space Agency workshops on basic space science, 1991-2000

37. The principal national organizers and participants of workshops have reported, on a continuous basis, on results addressed at and achieved through the workshops. Contact addresses of the principal national organizers at the host institutions can be used to receive updated information on all aspects of the workshops and their results published and reviewed in the international scientific literature. Relevant information is summarized in table 4.

IV. Mauritius Radio Telescope

38. The Mauritius Radio Telescope was designed primarily to undertake a survey of the southern sky at 151.5 megaHertz (MHz) with a sensitivity of 150 milliJansky. It is also meant to map the Milky Way. A point source catalogue of around 100,000 objects will be produced. The Mauritius Radio Telescope also makes observations of pulsars. Three surveys of the southern sky have already been finalized, with about 300 gigabytes of raw data collected.

Table 1
United Nations/European Space Agency workshops on basic space science, 1991-2001

Year	*City*	*Target region*	*Host institution*	*Number of participants*	*Number of participating countries*	*Workshop title*	*Report*
1991	Bangalore (India)	Asia and the Pacific	Indian Space Research Organization	87	19	Basic space science	A/AC.105/489
1992	San José and Bogotá	Latin America and the Caribbean	University of Costa Rica and University of the Andes	122	19	Basic space science	A/AC.105/530
1993	Lagos	Africa	University of Nigeria and Obafemi Awolowo University	54	15	Basic space science	A/AC.105/560/Add.1
1994	Cairo	Western Asia	National Research Institute of Astronomy and Geophysics	95	22	Basic space science	A/AC.105/580
1995	Colombo	Asia and the Pacific	Arthur C. Clarke Institute for Modern Technologies	74	25	Basic space science: from small telescopes to space missions	A/AC.105/640
1996	Bonn	Europe	Max Planck Institute for Radioastronomy	120	34	Basic space science: ground-based and space-borne astronomy	A/AC.105/657
1997	Tegucigalpa	Latin America and the Caribbean	Universidad Nacional Autónoma de Honduras	75	28	Basic space science: small astronomical telescopes and satellites in education and research	A/AC.105/682
1999	Mafraq (Jordan)	Western Asia	Al al-Bayt University	95	35	Basic space science: scientific exploration from space	A/AC.105/723

Year	*City*	*Target region*	*Host institution*	*Number of participants*	*Number of participating countries*	*Workshop title*	*Report*
1999	Vienna	All regions	United Nations Office at Vienna			(a) Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III);	United Nations publication, Sales No. E.00.I.3
						(b) International Astronomical Union (IAU)/Committee on Space Research (COSPAR)/United Nations Special Environmental Symposium "Preserving the Astronomical Sky";	Ibid., annex III, sect. II
						(c) IAU/COSPAR/United Nations Special Workshop on Education in Astronomy and Basic Space Science	Ibid., annex III, sect. VIII
2000	Toulouse (France)	Europe	Centre national d'études spatiales	80	34	Basic space science: satellites and networks of telescopes; tools for global participation in the study of the universe	A/AC.105/742
2001	Reduit (Mauritius)	Africa	University of Mauritius	65	28	Basic space science: exploring the universe; sky surveys, space exploration and space technologies	A/AC.105/766

Table 2

Regional distribution of countries or areas and number of individuals who requested and received information on the results of the United Nations/European Space Agency workshops on basic space science in 2001

Africa		*Asia and the Pacific*		*Eastern Europe*		*Latin America and the Caribbean*		*Western Europe and other States*	
Algeria	31	Bahrain	1	Bulgaria	2	Argentina	6	Australia	4
Angola	1	Bangladesh	1	Croatia	2	Bolivia	1	Austria	6
Botswana	3	Brunei Darussalam	1	Czech Republic	6	Brazil	3	Belgium	7
Burkina Faso	1	China	13	Hungary	1	Chile	3	Canada	11
Burundi	2	India	38	Lithuania	2	Colombia	2	Denmark	3
Cameroon	6	Indonesia	8	Poland	5	Costa Rica	7	France	38
Central African Republic	1	Iran (Islamic Republic of)	2	Romania	3	Cuba	5	Germany	49
Côte d'Ivoire	3	Iraq	2	Russian Federation	16	Ecuador	2	Greece	5
Egypt	45	Japan	13	Slovakia	4	El Salvador	6	Ireland	1
Eritrea	1	Jordan	14	The former Yugoslav Republic of Macedonia	1	Guatemala	4	Israel	6
Ethiopia	3	Kazakhstan	3	Ukraine	2	Honduras	24	Italy	15
Gabon	1	Kuwait	9			Mexico	13	Malta	1
Ghana	10	Lebanon	5			Nicaragua	4	Netherlands	4
Guinea	4	Malaysia	2			Panama	3	New Zealand	1
Kenya	12	Mongolia	5			Paraguay	1	Norway	1
Liberia	1	Oman	4			Peru	4	Portugal	2
Libyan Arab Jamahiriya	11	Pakistan	7			Uruguay	6	Spain	14
Madagascar	4	Palestine	1			Venezuela	2	Sweden	3
Malawi	4	Papua New Guinea	1					Switzerland	3
Mali	1	Philippines	3					Turkey	8
Mauritania	3	Qatar	5					United Kingdom of Great Britain and Northern Ireland	15
Mauritius	4	Saudi Arabia	12					United States of America	110
Morocco	23	Singapore	2						
Mozambique	5								
Namibia	4								

A/AC.105/766

Africa		*Asia and the Pacific*		*Eastern Europe*	*Latin America and the Caribbean*	*Western Europe and other States*
Niger	2	Sri Lanka	6			
Nigeria	77	Syrian Arab Republic	6			
Rwanda	1	Taiwan Province of China	3			
Senegal	2	Tajikistan	1			
Sierra Leone	2	Thailand	4			
South Africa	113	United Arab Emirates	2			
Sudan	4	Uzbekistan	1			
Swaziland	2	Viet Nam	4			
Togo	1	Yemen	2			
Tunisia	8					
Uganda	3					
United Republic of Tanzania	5					
Zaire	2					
Zambia	8					
Zimbabwe	11					

Total number of countries: 124

Total number of individuals: 1,024

Table 3
Projects pursued through the United Nations/European Space Agency workshops on basic space science, 1991-2000

Year	*Country*	*World Wide Web site*	*Projects worked on at the workshop*	*Recommended follow-up projects*
1991	India		Telescope donation programme of the Government of Japan: Sri Lanka 1995, Paraguay 1999 and the Philippines 2000	Establishment of an astronomical facility at the Arthur C. Clarke Institute for Modern Technologies (ACCIMT) in Sri Lanka
1992	Costa Rica and Colombia	Galactic emission map (Colombia) http://aether.lbl.gov/www/projects/GEM/	Education and career development in basic space science "ISY92: Planetarium: A Challenge for Educators"	Establishment of an astronomical observatory for Central America in Honduras Donation of computer equipment by the European Space Agency (ESA): Cuba, Ghana, Honduras, Nigeria, Peru and Sri Lanka Establishment of a 5.5-m radio telescope in Colombia
1993	Nigeria	Inter-African astronomical observatory and science park (Namibia): http://home.t-online.de/home/a.masche/ and http://www.mpia-hd.mpg.de/Public/PUBREL/booklet01.html Southern African Large Telescope (South Africa): http://www.salt.ac.za	Southern African Large Telescope (South Africa)	Establishment of an inter-African astronomical observatory and science park on the Gamsberg in Namibia
1994	Egypt	Kottamia Telescope (Egypt) http://www.sti.sci.eg/scret/nriag.html	Kottamia Telescope (Egypt) Egyptian drill project for the Mars mission	Refurbishment of the Kottamia Telescope Participation of Egypt in the Russian Federation/United States of America Mars mission 2001
1995	Sri Lanka	ACCIMT telescope facility (Sri Lanka) http://www/slt/lk/accimt/	Inauguration of a telescope facility (Sri Lanka) World space observatory (WSO/UV)	Evaluation of the feasibility of a world space observatory
1996	Germany	Working Group on Space Science in Africa http://www.saao.ac.za/~wgssa/ Network of Oriental Robotic Telescopes (NORT) http://www.saao.ac.za/~wgssa/as2_nort.html	Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) Assessment of the achievements of the United Nations/ESA workshops	Establishment of NORT

Year	*Country*	*World Wide Web site*	*Projects worked on at the workshop*	*Recommended follow-up projects*
		Pierre Auger cosmic ray project: http://www.taridar.cnea.gov.ar/~auger/	Foundation of the Working Group on Space Science in Africa NORT 100-metre Effelsberg radio telescope Education and research using small astronomical telescopes Developing astronomy and space science worldwide Two air shower detectors, one situated in the northern hemisphere (United States of America) and one in the southern hemisphere (Argentina)	
1997	Honduras	Observatorio Centroamericano de Suyapa (Honduras): http://www.unah.hn Space Guard Foundation (Italy): http://spaceguard.ias.rm.cnr.it/	UNISPACE III First issue of the newsletter *African Skies/Cieux Africains* published Inauguration of the Central American Astronomical Observatory in Honduras NORT Observation of near-Earth objects	Joint membership of Central American countries in the International Astronomical Union
1999	Jordan	Maragha Astronomical Observatory (Jordan): http://www.aabu.edu.jo/ Hands-on astrophysics: http://www.aavso.org/ Astrophysics education module for university physics courses: http://www.seas.columbia.edu/~ah297/un-esa/astrophysics/index.html	UNISPACE III WSO/UV Operation of the Maragha Astronomical Observatory in Jordan Baquaa radio telescope Hands-on astrophysics Astrophysics for university physics courses	Operation of the astronomical telescope facility at Al al-Bayt University Planning of the 31-m Baquaa radio telescope at the University of Jordan
2000	France	World space observatory/UV: http://www.seas.columbia.edu/~ah297/un-esa/wso.html	UNISPACE III WSO/UV NORT Regional newsletters on astronomy	WSO/UV assessment study completed

Table 4
Contact addresses and published results of the United Nations/European Space Agency workshops on basic space science, 1991-2000

Year	*Principal organizer*	*Published review of workshop*	*Working papers published in* Seminars of the United Nations Programme on Space Applications: Selected Papers from Activities	*Workshop proceedings*
1991	S. C. Chakravarty Indian Space Research Organization Antariksh Bhavan New BEL Road Bangalore 560 094 India scc@isro.ernet.in	*Astrophysics and Space Science*, vol. 193, 1992, p. 161.	One working paper each in Nos. 3 (1992) and 4 (1993).	*AIP Conference Proceedings*, vol. 245, 1992, pp. 1-350.
1992	Walter Fernandez School of Physics University of Costa Rica 2060 San José Costa Rica wfer@cariari.ucr.ac.cr	*Earth Space Review*, vol. 2, No. 2, 1993, pp. 25 and 26. *COSPAR Information Bulletin*, vol. 2000, No. 149, pp. 82-84.	No working papers published.	*Earth, Moon, and Planets*, vol. 63, No. 2, 1993, pp. 93-179.
1992	Sergio Torres Observatoria Astronómico Nacional Universidad Nacional de Colombia P.O. Box 2584 Santa Fe de Bogotá Colombia verada@earthlink.net	*Earth Space Review*, vol. 2, No. 2, 1993, pp. 25 and 26. *COSPAR Information Bulletin*, vol. 1999, No. 144, pp. 13-15.	No working papers published.	*Astrophysics and Space Science*, vol. 214, 1994, pp. 1-260.
1993	Pius N. Okeke Space Research Centre University of Nigeria Nsukka Nigeria misunn@aol.com	*Earth Space Review*, vol. 3, No. 3, 1994, pp. 26 and 27. *COSPAR Information Bulletin*, vol. 1999, No. 144, pp. 28-30.	Three working papers in No. 5 (1994).	*AIP Conference Proceedings*, vol. 320, 1995, pp. 1-320.

Year	*Principal organizer*	*Published review of workshop*	*Working papers published in* Seminars of the United Nations Programme on Space Applications: Selected Papers from Activities	*Workshop proceedings*
1994	Joseph S. Mikhail National Research Institute of Astronomy and Geophysics Helwan Cairo Egypt	*Earth Space Review*, vol. 4, No. 2, 1994, pp. 28-30. *COSPAR Information Bulletin*, vol. 2000, No. 148, pp. 41 and 42.	Three working papers in No. 6 (1995)	*Earth, Moon, and Planets*, vol. 70, Nos. 1-3, 1995, pp. 1-233. *Astrophysics and Space Science*, vol. 228, 1995, pp. 1-405.
1995	Padmasiri De Alwis Arthur C. Clarke Institute for Modern Technologies Katubedda, Moratuwa Sri Lanka asela@slt.lk	*COSPAR Information Bulletin*, vol. 1996, No. 136, pp. 8-11. *ESA Bulletin*, No. 81, February 1995, pp. 18-21.	Three working papers in No. 8 (1997)	
1996	Rolf Schwartz Max Planck Institute for Radioastronomy Auf dem Hügel 69 D-53121 Bonn Germany rolf@mpifr-bonn.mpg.de	*COSPAR Information Bulletin*, vol. 1997, No. 138, pp. 21-24. *AAS Newsletter*, No. 79, 1996, pp. 18 and 19.	Two working papers in No. 8 (1997)	*Astrophysics and Space Science*, vol. 258, 1998, pp. 1-394.
1997	Maria Cristina Pineda de Carias Observatorio Astronómico Universidad Nacional Autónoma de Honduras Apartado Postal 4432 Tegucigalpa M.D.C. Honduras Mcarias@hondutel.hn	*COSPAR Information Bulletin*, vol. 1998, Issue 141, pp. 9 and 10. *Annals of the New York Academy of Sciences*, vol. 822, 1997, pp. 621-630.	Six working papers in No. 9 (1998)	
1999	Hamid M. K. Al-Naimiy Higher Institute of Astronomy and Space Sciences Al al-Bayt University P. O. Box 130302 Al Mafraq Jordan Alnaimiy@yahoo.com	*COSPAR Information Bulletin*, vol. 1999, Issue 146, pp. 9 and 10.	Six working papers in No. 11 (1999)	*Astrophysics and Space Science*, vol. 273, 2000, pp. 1-343.

Year	*Principal organizer*	*Published review of workshop*	*Working papers published in* Seminars of the United Nations Programme on Space Applications: Selected Papers from Activities	*Workshop proceedings*
2000	François R. Querci Observatoire Midi-Pyrénées 14, avenue Édouard Belin F-31400 Toulouse France fquerci@ast.obs-mip.fr	*COSPAR Information Bulletin*, vol. 2000, No. 149, pp. 66 and 67. *AAS Newsletter*, No. 100, June 2000, p. 21. *AAS Newsletter*, No. 102, October 2000, p. 14.	Thirteen working papers in No. 12 (2001)	

39. The Mauritius Radio Telescope is a synthetic radio telescope that is utilized to take images of the sky at a frequency of 151.5 MHz (or 2-metre wavelength). It can detect objects that are too faint to be seen by large optical telescopes.

40. The telescope is a joint project of the Indian Institute of Astrophysics and the Raman Research Institute, both in Bangalore, India, and the University of Mauritius in Reduit. It is located in the Bras d'Eau forest in the rocky north-eastern part of Mauritius (20.14° S and 57.73° E).

41. The original idea of a southern sky survey at a frequency of 150 MHz was put forward by Ch. V. Sastry of the International Institute of Astrophysics. He had the intention of undertaking a survey equivalent to the Cambridge 6C survey of the northern sky. Mr. Sastry and V. Radhakrishna of the Raman Research Institute visited Mauritius in 1987 to set up the telescope. Its further development remains a joint project of the three institutions mentioned. The final construction was completed in 1992 and the telescope has been operational since then. The receiver system was donated by W. C. Erikson from the defunct Clarke Lake Observatory, University of Maryland (United States). The antenna system was designed and built in India.

42. At present, there are 17 individuals employed for the day-to-day operation of the Mauritius Radio Telescope. They have completed three surveys and a low-resolution map of the southern sky. The processing of data for the final map has been completed. Observations of specific southern sky pulsars were made.

43. As one result of the establishment and operation of the telescope, four PhDs, one MPhil and a number of BSc theses have been completed. Engineers and technicians have been trained in the establishment and operation of the telescope. Subsequently, research papers have been published and, in 1997, a conference on low-frequency radio astronomy was organized by the staff. The Mauritius Radio Telescope has achieved international recognition.

44. The Mauritius Radio Telescope is a T-shaped array consisting of 1,020 fixed helical antennas arranged in 32 groups in the east-west arm (2 km long) and 64 helical antennas on 16 movable trolleys in the north-south arm (880 m long). There is a single trolley in the northern arm of the telescope. The antennas collect the radio waves coming from space. The signal from each group is filtered, amplified and sent to the telescope building where it is combined with the signals from other groups. The signal is processed in a correlator and computer programs transform it into images or profiles.

45. The Mauritius Radio Telescope uses the technique of synthetic aperture to simulate a 1 km by 1 km filled array. Observations are made with the trolleys in the south arm at their nearest position from the centre of the array. The trolleys are then moved further south and the observations repeated 62 times. This process continues until the end of the south arm is reached. A computer system, operating with Linux OS, is used to collect the observations to produce a map of the sky. Unlike most radio telescopes, the Mauritius Radio Telescope can see very extended radio sources. Also, the non-coplanarity of the east-west arm has led to the development of new imaging techniques used in cleaning the raw data.

46. Although the telescope was designed primarily to conduct the 151.5 MHz survey, it has also been used for pulsar observations, for which only the east-west arm is used. The group outputs are added together with a tracking capability of about 20 pulsars for a source transiting at meridian. This corresponds to eight minutes for an equatorial source. Data are recorded at a fast rate over a bandwidth of 1 MHz. The data processing is done to produce an output in the desired format, including the profile unique to each pulsar.

Notes

[1] See *Report of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space, Vienna, 19-30 July 1999* (United Nations publication, Sales No. E.00.I.3), chap. I, resolution 1, part I, para. 1 (e) (ii), and chap. II, para. 409 (d) (i).

[2] *Official Records of the General Assembly, Fifty-fifth Session, Supplement No. 20* (A/55/20), para. 37.

United Nations A/AC.105/767

General Assembly

Distr.: General
28 November 2001

Original: English

Committee on the Peaceful Uses of Outer Space

Report on the Eleventh United Nations International Training Course on Remote Sensing Education for Educators

(Stockholm and Kiruna, Sweden, 2 May-9 June 2001)

Contents

		Paragraphs	Page
I.	Introduction	1-5	2
	A. Background and objective	1-2	2
	B. Organization and programme	3-5	2
II.	Summary of the contents of the course	6-14	2
III.	Course evaluation	15-19	3
IV.	Evaluation of the impact of the series of training courses on curriculum development	20-27	4
V.	Follow-up action	28-30	5

V.01-89039 (E) 201201 211201

I. Introduction

A. Background and objective

1. The Eleventh United Nations International Training Course on Remote Sensing Education for Educators, held in Stockholm and Kiruna, Sweden, from 2 May to 9 June 2001, was organized by the United Nations Programme on Space Applications of the Office for Outer Space Affairs of the United Nations Secretariat in cooperation with the Government of Sweden as part of the 2001 activities of the Office for Outer Space Affairs. As was the case for the 10 previous courses in the series, the course in 2001 was conducted specifically for the benefit of educators from developing countries with the objective of enabling them to introduce remote sensing courses in their respective academic institutions. It was co-sponsored by the Swedish International Development Cooperation Agency (Sida) on behalf of the Government of Sweden and was hosted by the Department of Physical Geography and Quaternary Geology of the University of Stockholm in Stockholm and by Metria Satellus AB (formerly SSC Satellitbild), in Kiruna.

2. The present report describes the organization of the training course, its technical contents, the results of the course evaluation and proposed follow-up action. It has been prepared for consideration by the Committee on the Peaceful Uses of Outer Space at its forty-fifth session and by its Scientific and Technical Subcommittee at its thirty-ninth session, in 2002. Participants have reported on the knowledge acquired and on the work conducted during the course to the appropriate authorities of the Government, universities and research institutions in their respective countries.

B. Organization and programme

3. Application forms for and information brochures on the training course were sent out in November 2000 by the Office for Outer Space Affairs to the permanent missions to the United Nations of 51 developing countries. Copies were also sent to the local offices of the United Nations Development Programme in those countries for transmission to the relevant national authorities. The same materials were distributed simultaneously to relevant Swedish embassies and to previous course participants for circulation in their academic institutions. One hundred and six completed applications from 34 developing countries were subsequently received and processed jointly by the Office for Outer Space Affairs and the University of Stockholm.

4. Twenty-six candidates, including 8 women, were selected as participants from the following 22 countries: Angola, Bangladesh, Chile, Costa Rica, Ethiopia, Ghana, Guyana, Haiti, Kenya, Malawi, Mozambique, Nepal, Nicaragua, Pakistan, Senegal, Sri Lanka, Swaziland, Thailand, Trinidad and Tobago, United Republic of Tanzania, Viet Nam and Venezuela. Funds for the international travel of 13 participants were provided from the fellowship budget of the United Nations Programme on Space Applications. Support for the international travel of the remaining 13 participants, as well as the cost of room and board, course materials and inland transport for all 26 participants, was provided by the Government of Sweden. The European Space Agency (ESA) funded the participation of one course instructor.

5. Course instructors and speakers came from several institutions, including the Office for Outer Space Affairs, ESA, Sida, the University of Stockholm, the Swedish Royal College of Technology, the University of Uppsala, the Swedish National Space Board, L & L Monitor AB and Metria Satellus AB.

II. Summary of the contents of the course

6. Except for minor modifications to reflect technological advances and feedback received during annual course evaluations, the core content and structure of the course have not changed significantly over the years. The course is modular in format and consists of a series of lectures and office and field exercises. A more detailed summary of the contents of the course can be found in the report on the fifth course in the series (A/AC.105/617).

7. The first technical module of the course lasted four days and dealt with the fundamental principles of remote sensing. The principal topics covered were electromagnetic radiation, the reflective properties of various types of material on the surface of the Earth and elementary optics; electronic imaging;

georeferencing of objects in the field, on maps and on satellite imagery; Earth resources and environmental satellites; and remote sensing for land use planning and environmental monitoring.

8. Four days were subsequently devoted to image interpretation and presentations on the introduction to visual interpretation and in-service training in developing countries and on applications of remote sensing.

9. To reinforce understanding of the principles of image interpretation, participants were divided into groups on a regional basis; each group studied a case where visual interpretation of satellite images played a key role.

10. The next series of lectures dealt with digital image processing and analysis and geographic information systems (GIS). That part of the programme lasted six days and covered the following subjects: digital analysis (theory); computer image enhancement (theory); GIS theory; and digital image processing techniques, including computer-aided analysis, GIS applications, CD-ROM data capture, compass techniques and global positioning systems (GPS).

11. The participants were also introduced, over a period of five days, to the principles of radar image formation and the use of such images in various development and research applications. There were additional lectures on and practical training in GIS. In addition, the participants were introduced to the use of appropriate procedures for the field verification of interpretation of remotely sensed data using Landsat TM images of the Skinnskatteberg area in southern Sweden.

12. The next part of the course was held in Kiruna, at the facilities of Metria Satellus AB. Seven days were reserved for visual interpretation in project planning exercises and presentation of results, as well as for digital classification of satellite images and comparison of the results of visual and digital interpretation. Wherever possible, exercises were carried out on images selected by the participants of areas of their countries with which they were familiar. Lectures were also presented on the following subjects: archiving, catalogue updating and standard production of images; image processing, value-added production, radiometric and geometric corrections, digital elevation model (DEM) production; standard and higher-level processed imagery; and future Earth resource satellites.

13. While in Kiruna, technical visits were arranged for the participants to a number of sites of interest, including the ESA Salmijärvi and Esrange satellite receiving stations. Lectures were supplemented by a tour of the production facilities of Metria Satellus AB.

14. The final part of the course concerned the development of remote sensing curricula and was held over a period of three days in Stockholm at the Department of Physical Geography and Quaternary Geology. The participants worked in small groups set up on a regional basis and on the last day of this part of the course each group presented a sample remote sensing curriculum project, which, in addition to educational content, included such components as necessary teaching staff and equipment and required budget. The participants also received and took back home sets of teaching materials, which included books, teachers' notes, slides and images, as well as a compact disc with satellite data and GIS and image-processing software.

III. Course evaluation

15. On the last day of the course, during a half-day evaluation session, participants made a formal presentation of the course evaluation to representatives of the Office for Outer Space Affairs, the Department of Geography and Quaternary Geology and several course lecturers. Discussions following the formal presentation by the representative of the participants allowed additional inputs to be made by all participants.

16. During the formal presentation and discussions, participants emphasized that the training programme was well organized and that the course had achieved its major goal. They also made some suggestions, which they believed would improve the programme of the course in the future. The main suggestions and recommendations made were as follows: (a) advanced training in remote sensing and GIS should be organized for selected participants as a follow-up to the programme; (b) a special newsletter should be prepared and distributed to former participants in order to share ideas, to facilitate the exchange of experience and knowledge and to discuss educational opportunities;

(c) more stimulating teaching methods should be used at the course, including more interaction between instructors and participants, as well as more time allocated for practical exercises; and (d) teaching notes and other course-related materials should be distributed among participants in advance.

17. In order to evaluate the general organization of the training programme, a questionnaire prepared by Sida was distributed to participants during the final part of the course. A summary of the opinions of the participants derived from the 22 completed questionnaires is as follows: (a) 64 per cent thought the course was right in length; (b) 41 per cent found the schedule too heavy, while 59 per cent thought the daily schedule was right; (c) 55 per cent found that the theoretical training corresponded to their professional needs to a large or very large extent and 41 per cent said the same about the practical training; (d) 86 per cent found the overall level of the programme to be adequate from their personal professional point of view; (e) 55 per cent found that there were subjects not adequately covered in the programme, with most of them indicating geo-referencing, microwave remote sensing, digital techniques and GIS as requiring more attention; (f) 64 per cent found the methods of instruction to be very good; and (g) 50 per cent found the content of the programme relevant to their professional environment to a great or very great extent and 45 per cent thought that they would have an opportunity to apply the newly acquired knowledge and experience in their present employment to a great or very great extent.

18. The feedback received from the questionnaire will be taken into account in the development of the course programme for 2002, as, for example, recommendations made by participants in 2000 led to the extension of teaching in the practical use of GIS, as well as in digital image processing, in 2001.

19. At the conclusion of the discussions, the participants expressed their appreciation to the Government of Sweden, Sida, the University of Stockholm and the United Nations for making possible their participation in the training programme.

IV. Evaluation of the impact of the series of training courses on curriculum development

20. In 2001, the Office for Outer Space Affairs, in cooperation with the University of Stockholm, carried out a survey whose primary objective was to evaluate the impact that the series of United Nations/Sweden training courses had had on curriculum development and educational and research programmes at the local level, as well as to review the experience of past participants in the training course in introducing remote sensing into educational curricula and subsequently to determine the course's future direction, format and content. It was anticipated that the information received both from former participants and the academic administrations of their institutions would assist in determining the type of further training or other support needed by former participants and their respective universities and institutions.

21. The survey was conducted by means of two questionnaires developed by the Office for Outer Space Affairs in consultation with the University of Stockholm. The first questionnaire targeted former participants who had attended training courses between 1990 and 2000 and the second questionnaire was sent to the heads of departments, universities and institutions whose staff had participated in the courses.

22. The questionnaires addressed primarily the results of utilizing at the local level the knowledge gained in Sweden. In the substantive sections of the questionnaires, the respondents (both former participants and administration) were asked to indicate what had been the major impact of the training, whether curriculum development, introduction of new or enhancement of existing educational programmes or initiating or strengthening research or applications projects. Participants were also requested to describe in detail both their experience and the main obstacles to either introducing or enhancing remote sensing education in their institutions they had encountered in applying the knowledge gained. Other questions addressed such issues as support received by participants from the administration of their departments or universities, use of teaching materials/imagery/notes they had brought back from Sweden, the number of students who had benefited from the knowledge transmitted to them by former

participants in the course and the use of remote sensing in support of development programmes or projects that were of national importance.

23. Other sections of the questionnaires dealt with general information on former participants and/or their respective institutions, as well as with details of their participation in the United Nations/Sweden training course (year of participation, number of educators from the respondent's institution attending the course, etc.). The questionnaires also had a recommendation section, where former participants and the administrations of their institutions were requested to provide suggestions on further enhancement of the United Nations/Sweden training course, as well as to describe needs for supplementary training and other kinds of assistance required for the successful application of the knowledge received in the course to either introducing or enhancing remote sensing education at the local level.

24. The results of the evaluation survey showed that the training has been a very successful exercise, which, over a 10-year period of time, had allowed educators from developing countries to introduce remote sensing as a tool in the curricula of fields such as agriculture, forestry and civil engineering. This had given the course a high profile and excellent reputation among academic institutions in developing countries. Taking into account the main objective of the course, the series had succeeded in its efforts to train a large group of well-motivated and active professionals capable of developing sustainable educational programmes in remote sensing and GIS at the local level and of using remote sensing in projects that supported development programmes in their respective countries.

25. The survey showed that former participants had been active in applying the knowledge gained in Sweden to enhance existing or introduce new educational programmes in remote sensing and GIS in their respective institutions, as well as in developing curricula or using the knowledge acquired in research or applications projects.

26. The survey also showed that the major obstacle to the ability of former participants to apply the training received in Sweden was lack of funding for the acquisition of the satellite images and data, computer hardware and software, training and reference materials necessary for successful and effective teaching of such an advanced discipline as remote sensing.

27. In addition, the survey clearly demonstrated a strong need for supplementary training in advanced disciplines (digital data processing, GIS, GPS and use of high-resolution data), as well as for periodic training for former participants in order to help them keep abreast of the latest technological developments. Support in organizing joint projects and in establishing academic links and staff exchange programmes was also required.

V. Follow-up action

28. Taking into account the objectives of the course and the results of the survey, the Office for Outer Space Affairs has proposed a number of activities that could be taken in order to increase the success of the programme in the future and to enhance the local impact of the United Nations/Sweden training courses.

29. The proposed follow-up activities include, among other things, the continuation of the practice of selecting qualified former participants in the course for participation in the United Nations/ESA long-term fellowship programme, as well as providing former participants with more short-term training opportunities through the activities organized by the United Nations Programme on Space Applications. It has also been proposed that direct connections between the regional centres for space science and technology education and participants should be established in order to provide the latter with both additional training opportunities and assistance in curriculum development.

30. Detailed information on the results of the evaluation survey as well as proposed follow-up actions will appear in the report on the survey on the local impact of the series of United Nations/Sweden international training courses on remote sensing education for educators (1990-2000) (ST/SPACE/9).